

OTR Diagnostics in the AWAKE Experiment

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Karl Rieger, M. Martyanov, P. Muggli

rieger@mpp.mpg.de, mmartyan@mpp.mpg.de, muggli@mpp.mpg.de

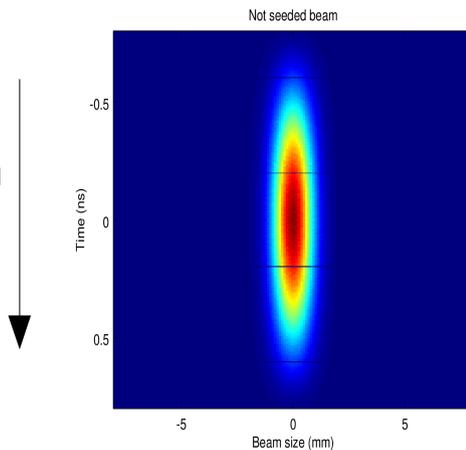
- The Awake proton bunch and SMI
- OTR Diagnostic in AWAKE
- SPS proton testrun
- Conclusion

The Awake SMI

The proton beam evolves in the plasma to microbunches

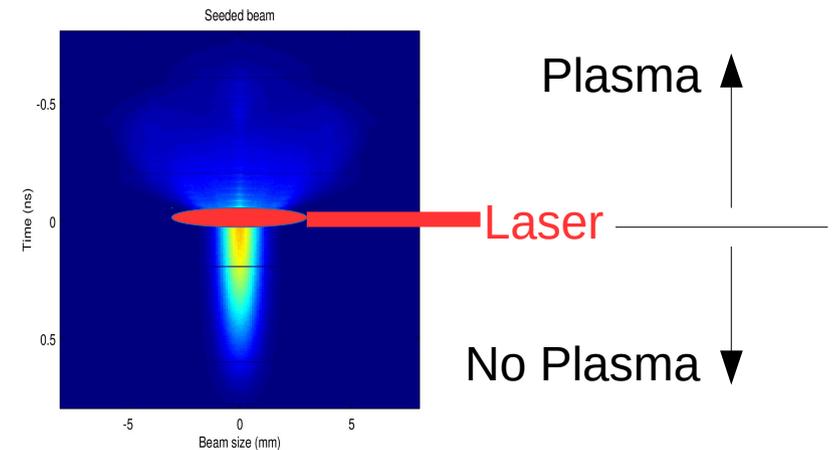
Plasma OFF

Propagation
direction of
beam



Seeding of
smi

Plasma ON



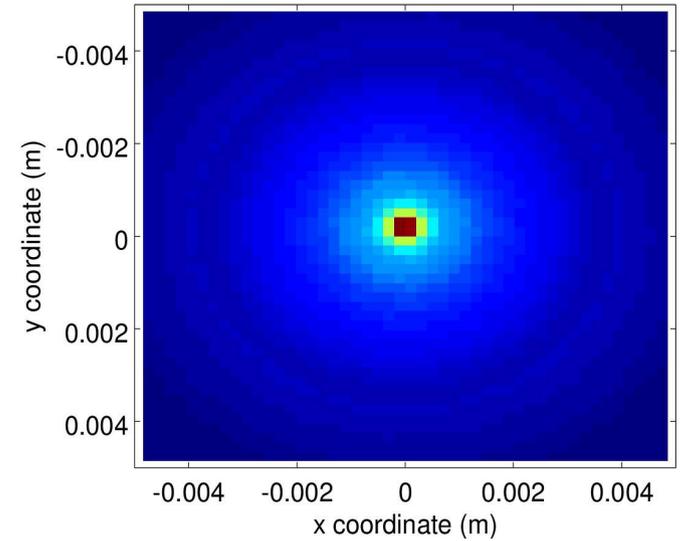
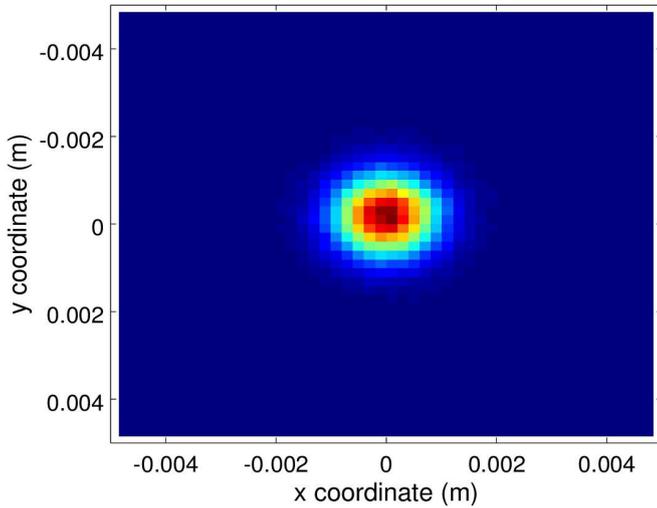
- Long SPS (~ns) driving bunch is no good driver for AWAKE plasma ($n_{pe} \sim 10^{14}-10^{15}$)
- Plasma – beam interaction modulates the bunch -> driving beamlets

- $3e11$ protons per bunch
- ~1.4 ns (2σ) long

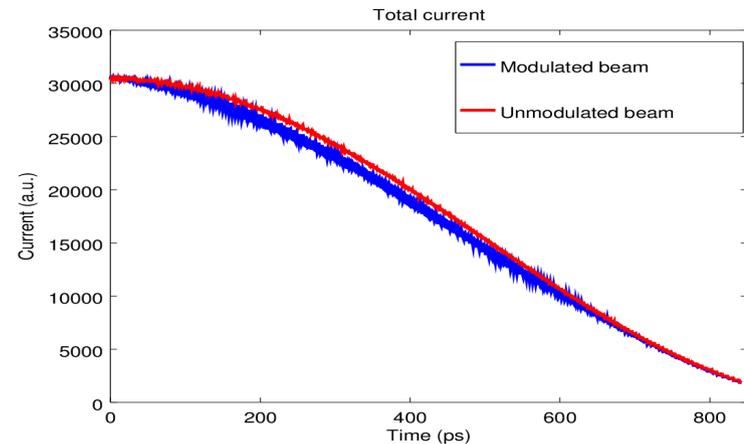


AWAKE SMI

Self modulation is current conserving

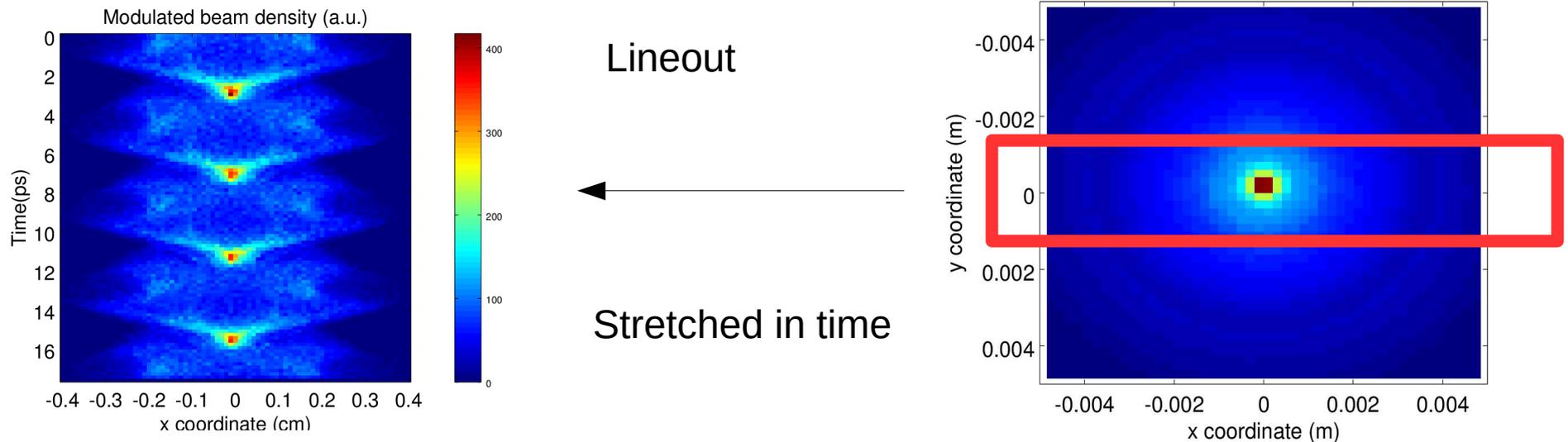


Front view of beam: the modulated beam has a core and a halo
But the current is conserved



➔ SMI Diagnostics M. Turner

Self modulation frequency on short timescale



- Beam has a substructure on scale of plasma wavelength/frequency
 - efficiently drives wakefields
- AWAKE: Plasma frequency $\sim 90\text{-}300\text{GHz}$ (\leftrightarrow $\sim 1\text{-}3\text{mm}$ wavelength)
 \rightarrow proton “bunchtrain” with $\sim 2\text{-}5\text{ps}$ time difference between two bunches

OTR in AWAKE

Time resolved measurements of the beam needed. Spatial also preferred

- Need timeresolved measurement of the beam
- Resolving beam spatially gives additional information

OTR:

- is prompt
- easy to operate
- good spatial resolution

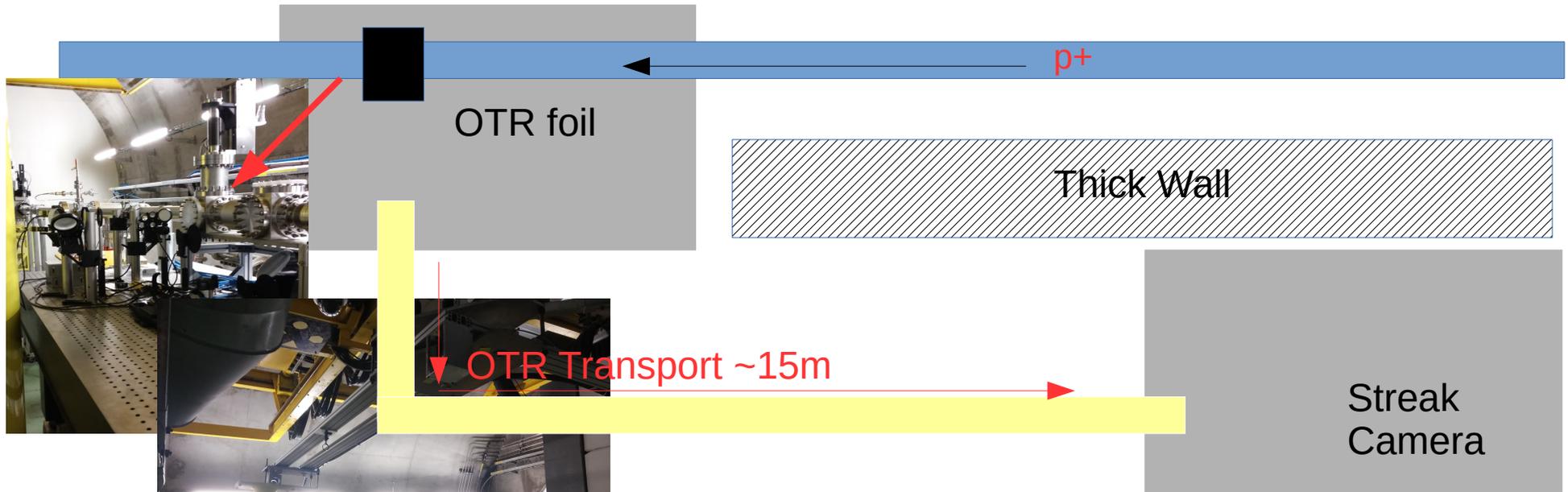
Device:

- Streak camera
 - offers \sim ps level time resolution
 - offers spatial resolution along one axis



OTR in AWAKE

Time resolved OTR setup in AWAKE – Imaging the OTR foil

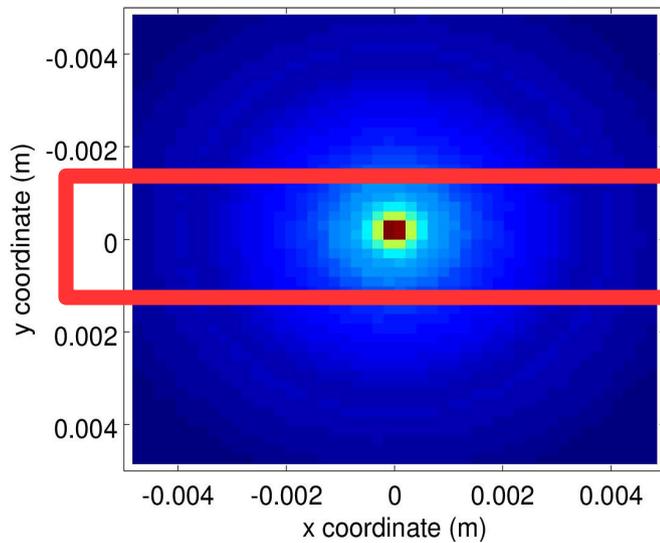


- Creation of OTR and collection
- Transportation of OTR
- Focussing to streak camera (imaging the foil)
- Additionally: 2 Photodiodes & 2 CCD's



OTR in AWAKE

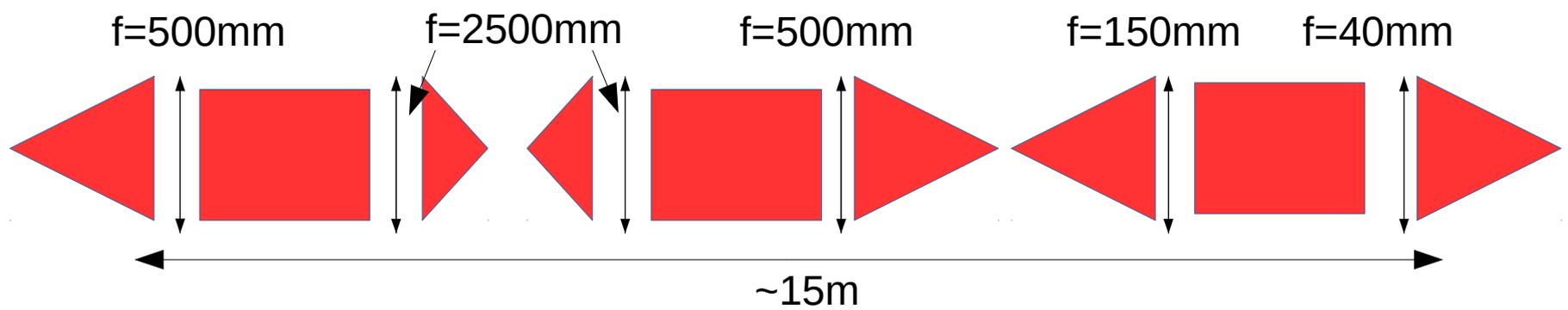
Streak slit creates cutoff and creates modulation



Limited by streak slit & imaging demagnification

- OTR foil is imaged to streak slit
- Transport line cuts off OTR from particles that are off axis

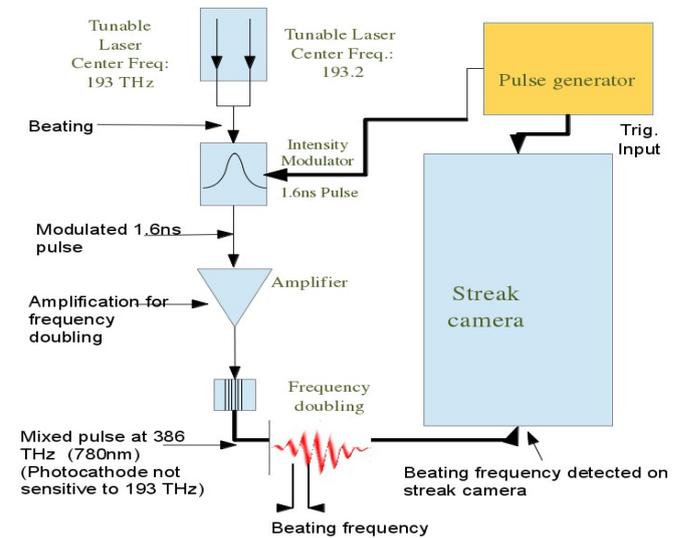
- Imaging system: ~3:1 demagnifying system
- Design wavelength: 450nm,



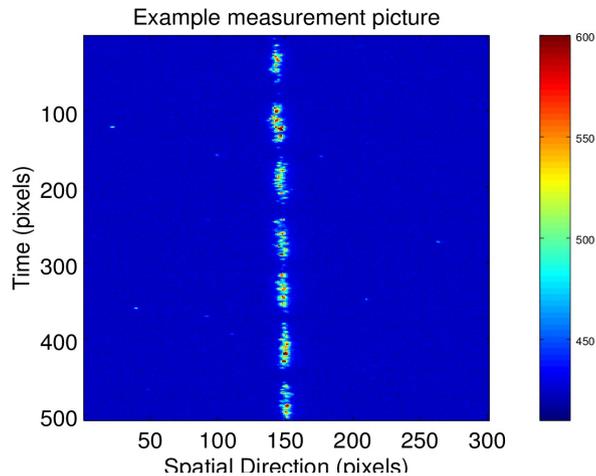
OTR in AWAKE

Streak camera is able to resolve <4ps modulated bunch

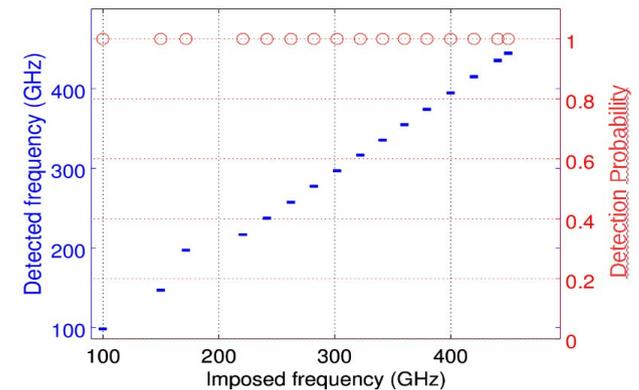
- We did tests by letting two laser beat at 50-450 Ghz (AWAKE 90-300GHz, design ~250GHz)
- Detect Modulation up to 450GHz
- Single event detection



150 Ghz example Image



100% detection up to 450GHz

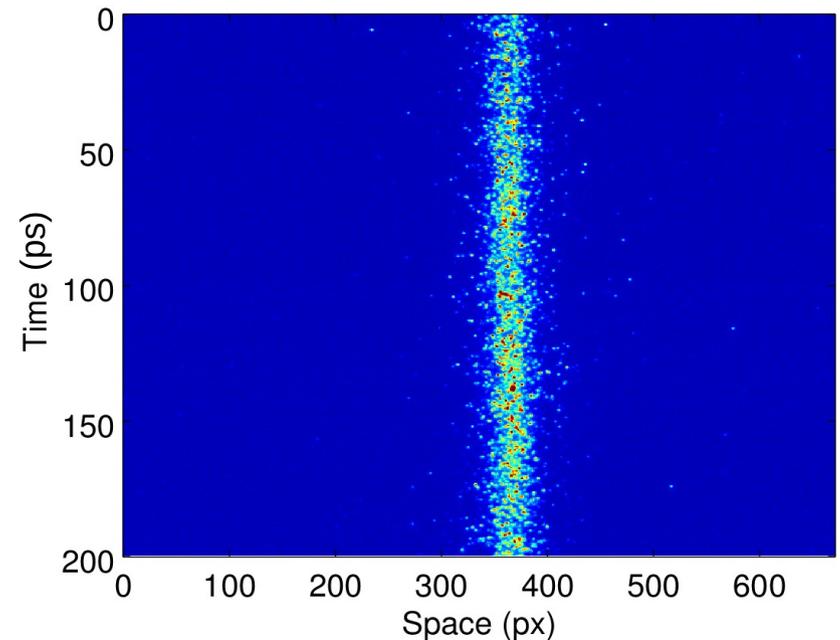
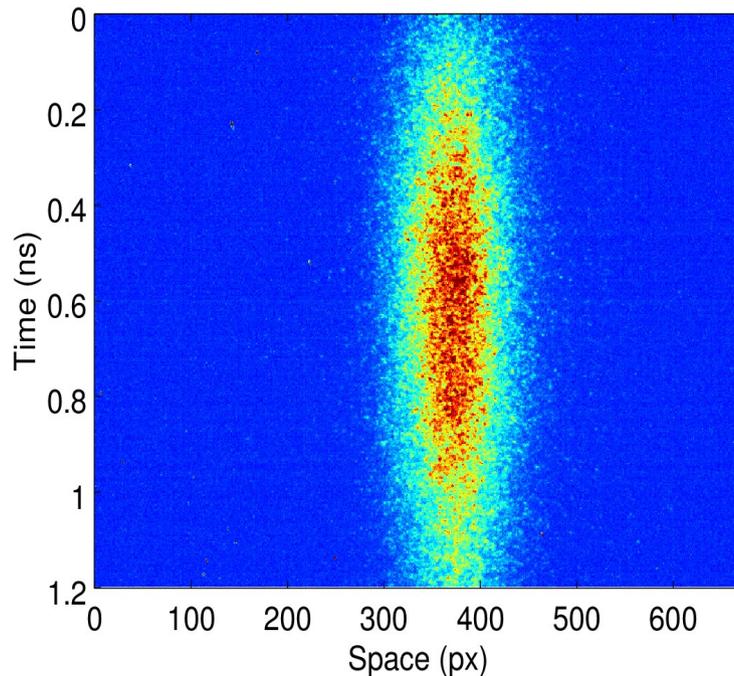




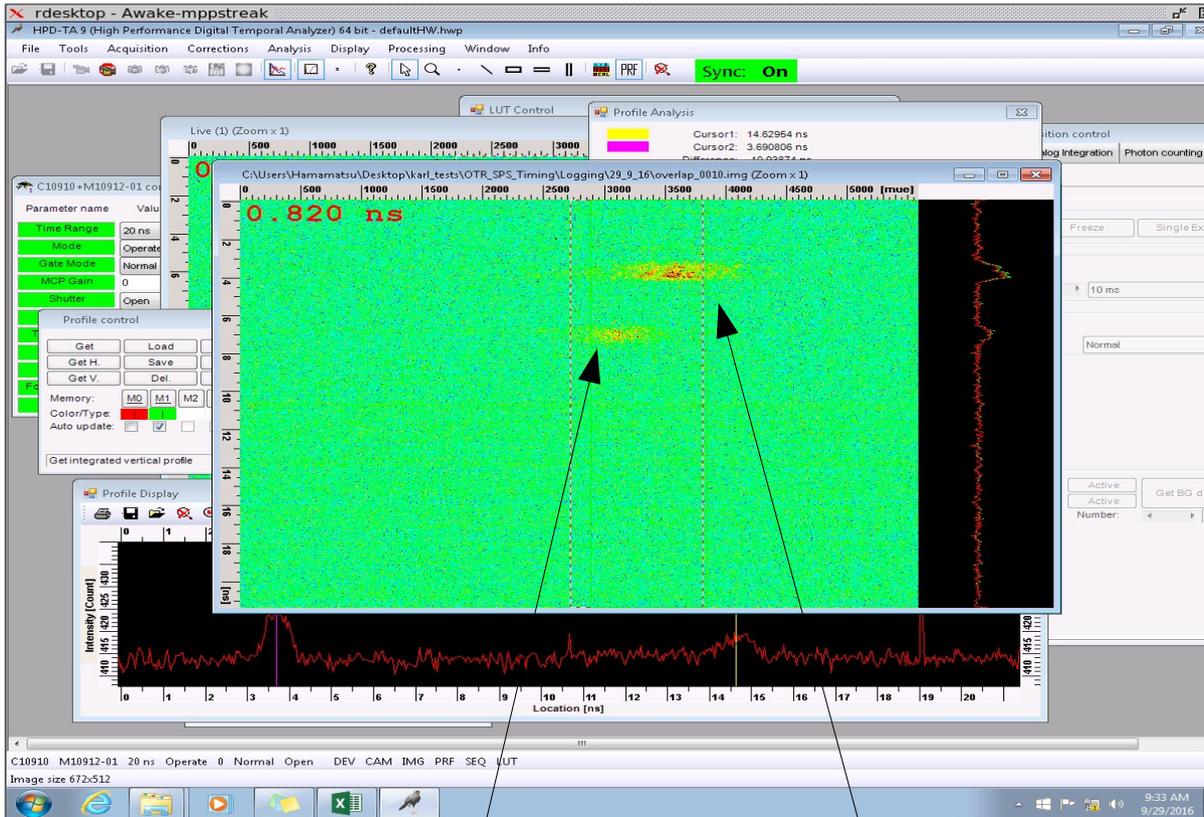
Demonstration

First protons were sent to AWAKE in September, streaked

- We were able to image and streak proton bunch
- Enough OTR light is transmitted (even large enough signal on low timescales)
- AWAKE Goals achieved: Synchronization of SPS and AWAKE laser
- OTR Bandwidth used: 400-500nm



AWAKE Laser and protons synchronized



Protons

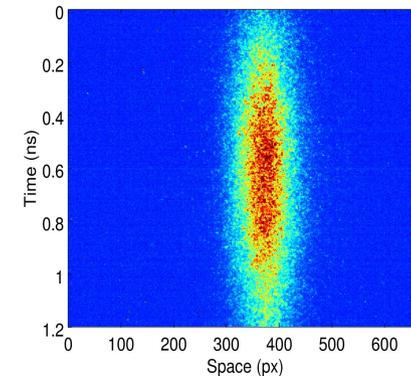
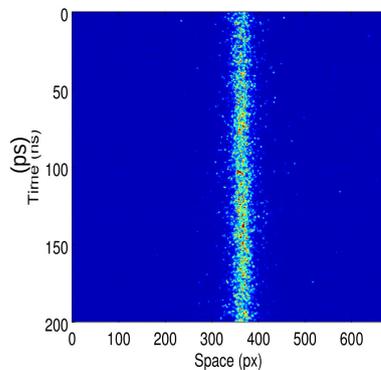
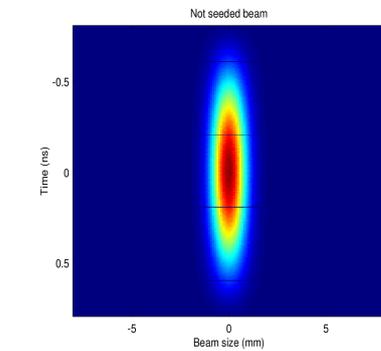
Laser

- After commissioning OTR:
- Time overlap between Laser and proton bunch
- > achieved and is now overlapping
- High precision laser/proton/electron alignment: Steffano Mazzone, Aurelie Goldblatt, Bartolomeij Biskup (all CERN)

Conclusion

OTR in AWAKE operational

- Experimental Diagnostics proven to work for low current
- Experimental Diagnostics fully installed and operational (commissioned)
 - SPS proton bunch synchronized with the AWAKE Laser
- Waiting for AWAKE experimental beam with plasma

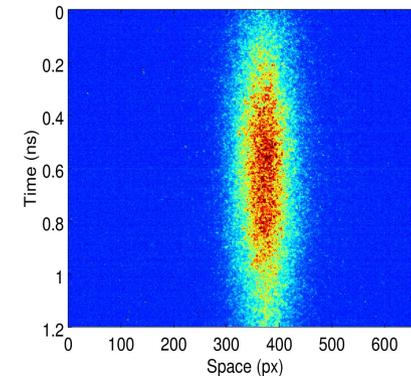
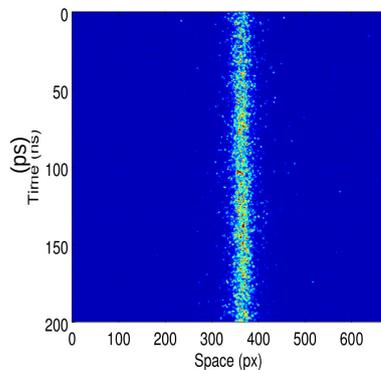
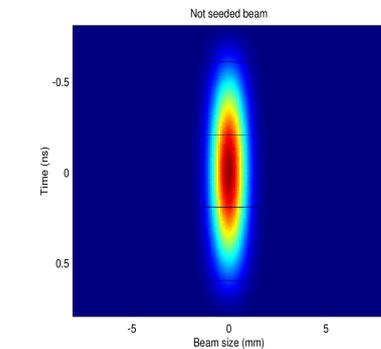


Thanks for your attention!

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Thanks for your attention!